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Sajan, Inc.
625 Whitetail Blvd.
River Falls, WI 54022
877.426.9505 phone
715.426.0105 fax
www.sajan.com

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SAJAN, INC.

By: Angel Zimmerman
Angel Zimmerman
Director of Operations

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Title

Procedure and arrangements for spatially perceptible presentations.

Scope of the invention

The invention covers the procedure and arrangements for spatially perceptible representations, in particular one that presents a spatially perceptible image to several viewers without requiring auxiliary means such as eyeglasses.

State of the art

There are many know specialized approaches for this application area. Particularly spread are the lenticular systems, the barrier systems and the filter array systems. The applicant describes, among other things, the latest technology procedures and arrangements in WO 01/56265 and WO 03/024122.

However, with the aforementioned arrangements and procedures, a drawback frequently arises: that from a comfortable 3D viewing distance, the respective 3D optic effect is dissolvable for a normally sighted human eye, for example in the filter array, and thus a certain undesired image effect takes place. Furthermore, the perceptible resolution is reduced and/or affected by the 3D optics.

The purpose of the invention is to arrange the structure of the 3D optics for the naked eye as sharply as possible, and to improve the quality of the spatially perceptible representation.

In this regard it is well-known that for the normally sighted human eye with a visual acuity of S=1, two neighboring points under a viewing angle of approximately less

than one arc minute (equivalent to approximately 0.017° in decimally divided degrees) are no longer dissolvable.

Description of the invention

The purpose of the invention is to solve this issues when a spatially perceptible representation of an image is being displayed, for which a group of individual picture elements α_{ij} in a matrix with j lines and i columns are made visible at the same time, so that

- the picture elements α_{ij} show partial information from several views A_k (k=1... n) of the scene/subject,
- a structural plate makes possible to force the propagation direction of the light emitted from the α_{ij} picture elements, and for this purpose the plate will have multiple optical elements arranged in series,
- the propagation directions within the viewing area in which the viewers are, cross with the multiple intersections which correspond in each case to a viewing position,
- from each viewing position, a viewer optically perceives with one eye the partial information of a first selection and with the other eye he optically perceives the partial information of a second selection from the A_k views (k=1... n), where the invention complies with the requirement that the corresponding average geometrical distance p' between two adjacent light-transmitting optical elements on the structural plate fulfills the $p' \leq p$ condition, on which $p=G * \sin(0.017°)$, where G is the quadruple of the diagonal length of the α_{ij} picture elements matrix.

When the aforementioned unequation is fulfilled, it causes that a normally sighted viewer with a visual acuity of S=1, who is watching the picture elements on the matrix from a viewing distance of the quadruple of the diagonal length of the matrix, cannot visually dissolve any longer two adjacent light-transmitting optical elements. With this, an improved spatially perceptible representation is achieved.

To that effect, the mentioned unequation can only get worse, when the average geometrical distance p' which corresponds to two adjacent successive light-transmitting optical elements on the structural plate fulfill the $p' \leq p''' \leq p$ condition, on which p" '=H * sin (0.017°), where H is two-and-one-half times the diagonal length of the picture elements matrix α_{ij}. Thereby a normally sighted viewer with a visual acuity of S=1 would not visually dissolve any more the adjacent light-transmitting optical elements from a viewing distance of two-and-one-half times the diagonal length of the matrix.

It is also possible to shape an even smaller average geometrical distance p', so that likewise those viewers with a visual acuity of S >1 do not visually dissolve any more the adjacent successive light-transmitting optical elements from the mentioned viewing distance.

It is advantageous to include in a structural plate several cylindrical lenses as light-transmitting optical elements arranged in p columns and q lines. In further arrangements, polarization filters, holographic-optical elements or spherical and aspheric lenses can be used as optical elements.

However, it is preferable that the structural plate includes several transparent filtering elements as light-transmitting optical elements, arranged in p columns and q lines. The transparent filtering elements are respectively located on the structural plate at least partially between basically opaque filtering elements.

For this arrangement, the transparent filter elements - essentially the entire visible light - are arranged in a rectangular shape, preferably staggered between each other, whereby preferably each two partially overlap themselves respectively in adjacent lines or columns.

Such a structural plate can easily be made from exposed photographic film, which incorporates the transparent and the opaque filter elements and which is laminated on a glass plate. Further arrangements are conceivable.

Apart from that, likewise can be used filter elements which are respectively translucent for light of selected wavelengths or wave ranges.

The partial information of the first and the second selections from the A_k views (k=1... n), which a viewer optically perceives with one eye and with the other, correspond in each case to the exact partial information of one or several A_k views (k=1... n), whereby, for example, the viewer predominantly notices with each eye the corresponding mentioned partial information for the first and second selections. This last mentioned issues are described by the applicant in more detail in DE 100 03 326 C2. In addition, it can also be favorable, if the viewer sees accurately with each eye the mentioned partial information for the first and second selections, and if these selections cover in each case a precise A_k view (k=1... n). The applicant refers to PCT/EP2004/004464 in this regard.

A further advantageous configuration of the invention's procedures provides that the viewing area, within which the viewers may be experiencing a spatial impression, must include at least those levels which:

- are in a forwards viewing direction,
- are parallel to the α_{ij} image elements matrix, and
- are located within a distance of 2.5 or 4 times the diagonal length of the matrix.

The known procedures for spatially perceptible representations, which are based on lenticular or filter arrays, usually result in a preferential viewing distance for the viewer, from which the displayed 3D image is particularly well perceptible. These preferential distances can correspond, for example, to the aforementioned 2.5 times or 4 times the diagonal length of the matrix.

This way, the preferred viewing distance which becomes inseparably related to the corresponding (minimal) required distance for not dissolving visually the optical elements of the 3D optical effect (in this case, the optical elements on the structural plate).

Furthermore, the combined partial information can be favorably displayed from at least one image element α_{ij} with partial information of at least two different A_k views (k=1... n) of the scene/subject. The applicant describes this approach in broader detail in WO 03/024122, which allows adjusting the structure of the displayed image from the picture elements α_{ij} to the respective geometrical conditions of the used structural plate, in particular for a filter array.

The purpose of the invention is to solve the issue of an arrangement for the spatially perceptible representation of a scene/subject, including:

- an image rendering device with multiple individual picture elements α_{ij} in a matrix with j lines and i columns, on which the α_{ij} picture elements are the displayable partial information from several A_k views (k=1... n) of the scene/subject,
- at least one structural plate in the viewing direction in front or behind the image reproduction mechanism, arranged to force the required propagation direction of the light radiated from the α_{ij} picture elements, where the structural plate shows multiple optical elements arranged accordingly for this purpose,
- that the propagation directions within the viewing area in which the viewers are, cross with the multiple intersections which correspond to individual viewing positions, so that from each viewing position a viewer optically perceives with one eye the partial information of a first selection and with the other eye the partial information of a second selection from the A_k views (k=1... n), whereby according to the invention:
- the average geometrical distance p' for each of the two adjacent successive light-transmitting optical elements on the structural plate fulfill the $p' \leq p$ condition, on which $p = G * \sin(0{,}017°)$, where G is the quadruple of the diagonal length of the picture elements matrix α_{ij}.

The image rendering device with multiple individual picture elements α_{ij} in a matrix with j lines and i columns i can be, for example, a 17" TFT-LCD monitor like the ViewSonic VX700 or the 50" Pioneer PDP 503 MXE plasma monitor, on which the picture elements α_{ij} correspond to the RGB color sub pixels. An electronic control system, which can consist for example of a commercial PC, ensures that the α_{ij}

picture elements display the partial information from the different A_k views (k=1...n) of the scene/subject.

It is preferable to use a structural plate with several cylindrical lenses arranged in p columns and q lines as light-transmitting optical elements.

However, the structural plate will preferably include several transparent filter elements arranged in p columns and q lines as light-transmitting optical elements. Thereby, the transparent filter elements are respectively located on the structural plate at least partially between essentially opaque filter elements.

In this preferred arrangement, the transparent filter elements for the entire visible light are arranged in a rectangular array, preferably staggered between each other, where every two transparent filters partially overlap themselves respectively in adjacent lines and columns. Other forms than rectangular shapes are also feasible for the transparent filters.

Such a structural plate can easily be made from exposed photographic film, which incorporates the transparent and the opaque filter elements and which is laminated on a glass plate. Further arrangements are imaginable.

In a special arrangement of the configuration according to the invention, the average geometrical distance p' fulfills the $p' \leq p''' \leq p$ condition, for two contiguous successive light-transmitting optical elements on the structural plate, on which p'' '=H * sin (0.017°) applies, where H is two-and-one-half times the diagonal length of the picture elements matrix α_{ij}. Thereby the normally sighted viewer with a visual acuity of S=1 would not visually dissolve any more the adjacent light-transmitting optical elements already from a viewing distance of the two-and-one-half times one of the diagonal length of the matrix.

The partial information of first and the second selections from the A_k views (k=1... n), which a viewer optically perceives respectively with each eye, correspond in each case to the precise partial information from one or more the A_k views (k=1... n), whereby the viewer can perceive with each eye the preponderant or exclusive

mentioned partial information from the first and second selections.

A further advantageous configuration of the invention's configuration procedures considers that the viewing area in which the viewers are, must include at least those levels that:

- are in a forwards viewing direction,
- are parallel to the α_{ij} image elements matrix, and
- are located within a distance of 2.5 or 4 times the diagonal length of the matrix.

The known arrangements for spatially perceptible representations, which are based on lenticular or filter arrays, usually result in a preferential viewing distance for the viewer, from which the displayed 3D image is particularly well perceptible. These preferential distances can correspond, for example, to the aforementioned 2.5 times or 4 times the diagonal length of the matrix.

This way, the preferred viewing distance which becomes inseparably related to the corresponding (minimal) required distance for not dissolving visually the optical elements of the 3D optical effect (in this case, the optical elements on the structural plate).

Furthermore, at least one α_{ij} image element can displayed the combined partial information from the partial information of at least two different A_k views (k=1... n) of the scene/subject.

Brief description of the diagrams

The invention will be described in further detail on the following diagrams.
They illustrate:

Fig.1	Example of a filter array as a component of a structural plate in an invention-based arrangement,
Fig.2	A further example of a filter array,

Fig.3	An image composition structure usable in connection with the filter array shown in Fig.2,
Fig.4 and Fig.5	Example for the respective visible view mixtures for each eye, as well as
Fig.6	An illustration for the application of a compressed image composition based on the invention.

Detailed description of the diagrams

In an arrangement example, the invention-based configuration for spatially perceptible representation includes:

- an image rendering device with multiple individual picture elements α_{ij} in a matrix with j lines and i columns, on which the α_{ij} picture elements are the displayable partial information from several A_k views (k=1... n) of the scene/subject,
- one structural plate in the viewing direction in front or behind the image rendering device, that forces the required propagation direction for the light radiated from the α_{ij} picture elements, where the structural plate shows multiple optical elements arranged accordingly for this purpose,
- the propagation directions within the viewing area in which the viewers are, cross with the multiple intersections which correspond to individual viewing positions, so that from each viewing position a viewer optically perceives with one eye the partial information of a first selection and with the other eye the partial information of a second selection from the A_k views (k=1... n).

The structural plate includes several transparent filter elements arranged in p columns and q lines as light-transmitting optical elements. Thereby, the transparent filter elements are respectively located on the structural plate at least partially between essentially opaque filter elements.

In this preferred arrangement, the transparent filter elements for the entire visible light are arranged in a rectangular array, preferably staggered between each other, where every two transparent filters partially overlap themselves respectively in adjacent lines and columns. Other forms than rectangular shapes are also feasible

for the transparent filters. An example for the arrangement of the filter elements is shown in Fig.1.

Such a structural plate can easily be made from exposed photographic film, which incorporates the transparent and the opaque filter elements and which is laminated on a glass plate. Further arrangements are conceivable.

In Fig.1, a series of further transparent filters (F1, F2, F3) are intended to be used as optical elements, as it is schematically indicated (the diagram is not at full-scale). Preferably, the structure of the optical elements is developed periodically.
The distance of the two nearest contiguous elements can be easily calculated according to Fig.1 as follows:

Being 'u' the width and 'v' the height of the smallest structural sections which form the entire structure of the optical structural plate, with constant and complete repetition but without partial misalignment (like for example, misalignment around a third without changes) - in this case, the filter array. It furthermore applies that v=3*EZy*a and u=EZx*a. 'a' represents here a variable fundamental unit, while the factor 3 is introduced, in order to consider the RGB color sub pixel structure in cooperation with the dimensions of the filter elements.
The 'a' parameter depends proportionally on the size of the α_{ij} picture elements, i.e. if the size of the α_{ij} picture elements is reduced, then 'a' also becomes smaller.

...

Then equation (1) applies:

$$p' = 3 \cdot EZ_x \cdot EZ_y \cdot \frac{a}{\sqrt{EZ_x^2 + 3^2 \cdot EZ_y^2}}$$

For the special case that the series of transparent and opaque filters are not strictly arranged in series, but rather show variable distances between the transparent filter elements, the average distance - this is, the arithmetic mean of all the different individual distances p' – is relevant.

In particular, the geometrical distance of the main propagation directions of two adjacent series can be calculated as the distance of adjacent series of transparent filter elements. In Fig.1 and in Fig.2 such main propagation directions are represented for the series.

The implementation of the configuration example given in the conference is described in more detail next.

For this example, a 17" TFT-LCD ViewSonic VX700 monitor was used as an image rendering device with multiple individual α_{ij} picture elements in a matrix with j lines and i columns, where the α_{ij} picture elements correspond to the RGB color sub pixels. An electronic control, which can consist for example of a commercial PC, ensures that the partial information from several A_k views (k=1... n) of the scene/subject is displayed on the α_{ij} image elements.

For example, the illustration in Fig. 3 can be selected as an image rendering structure for the representation of the partial information from several A_k views (k=1... n) on the α_{ij} picture. The numbers in the small boxes correspond to the k numbers of the A_k views, from which the picture information comes from, which are displayed in the corresponding position in the matrix of the α_{ij} picture elements. The highest line "RGBRGB..." denotes that it handles the α_{ij} picture elements as the RGB color sub pixels of the image rendering device. For example, the 'a' quantity is directly proportional to the width of the α_{ij} picture elements, this is, the RGB color sub pixels.

With the mentioned 17" LCD monitor, the full color pixel distance is of 0.264 mm. Thus each RGB sub pixel is 0.264 mm high and 0.088 mm wide. An example of the filter array for the configuration shown in the conference is illustrated in Fig.2 (not at full-scale). In this example, v=3*EZy*a and u=EZx*a with EZy=8, EZx=4 as well as a=0.088 mm and f=0.087881022 mm, with f=65/65.088 = 0.998647 (correction factor for the transparent filter dimensions).

From the above mentioned equation (1), result values of p'=3.946 and of a=0.3467 mm for the case of the parameters mentioned for the filter illustrated in Fig.2.

As G is 4 times the diagonal length of the matrix, i.e. in this case of the 17" LCD, it results that G=1727 mm. Therefore, the above imported variable p= G * sin (0.017°) = 0.5125 mm.

Therefore, for this example applies the invention-based criterion that the average geometrical distance p' for two adjacent series of light-transmitting optical elements on the structural plate fulfills in each case the $p' \leq p$ condition, for which applies that $p=G * \sin (0.017^{\circ})$, where G is the quadruple of the diagonal length of the α_{ij} picture elements matrix.

In case that the 'a' value were smaller than the selected one, e.g. a=0.08 mm, then p'=0.316 mm. In this special arrangement, the average geometrical distance p' for two adjacent series of light-transmitting optical elements on an even structural plate fulfills in each case the $p' \leq p''' \leq p$ condition, for which applies that $p'' = H * \sin (0.017^{\circ})$, where H is two-and-one-half times the diagonal length of the α_{ij} picture elements matrix. Thereby a normally sighted viewer with a visual acuity of S=1 could not visually dissolve the adjacent series of light-transmitting optical elements from a viewing distance of 2.5 times the diagonal length of the α_{ij} picture elements matrix. Further improvements, like in particular the ongoing technical trend of reducing the width and height of the image rendering elements (e.g. with future image rendering devices), also serve indirectly for reducing the 'a' parameter; thus the aforementioned non dissolvability can be achieved from even shorter viewing distances than distance H. This is included in the context of the invention.

In the arrangement example, the partial information corresponds to the first and second selections from the A_k views (k=1... n), which a viewer perceives optically in both eyes the respective partial and precise information of one or several A_k views (k=1... n), whereby the viewer optically perceives with each eye in each case exclusively the mentioned partial information for the first and second selections. The applicant describes the above mentioned facts in further detail in DE 100 03 326 C2, as well as on Fig.4 and Fig.5. The vision of excluding partial view information per eye for achieving the spatial impression is described in the already mentioned PCT/EP2004/004464. An improved 3D impression is obtained by the non dissolvability feature of the optical elements.

The distance 'd' between the filter array and the structural plate and the surface of the image rendering device must preferably measure a few millimeters, for example, d=1.6 millimeter.

A further advantageous configuration of the invention's procedures provides that the viewing area must include at least those levels which:

- are in a forwards viewing direction,
- are parallel to the α_{ij} image elements matrix, and
- are located within a distance of 2.5 or 4 times the diagonal length of the matrix..

The known arrangements for spatially perceptible representations, which are based on lenticular or filter arrays, usually result in a preferential viewing distance for the viewer, from which the displayed 3D image is particularly well perceptible.

The preferred viewing distance 'w' is determined with the equation in devices with filter arrays, for example the above mentioned 17" LCD monitor, on which w=65mm * d/0.088 mm, where 'd' corresponds to the distance between the filter array and the image rendering surface of the LCD monitor. For the case of d=1.6 mm, it results that w=1181 mm. The actual viewing area stretches before and behind this distance in the viewing direction, so that basically the levels are parallel to the α_{ij} picture elements matrix at a distance of 2.5 or 4 times the diagonal length of the matrix enclosed in the viewing area. In special applications, the preferable viewing distance 'w' can also correspond for instance to the value of 2.5 or 4 times the diagonal length of the matrix.

This way, the preferred viewing distance which becomes inseparably related to the corresponding (minimal) required distance for not visually dissolving the optical elements of the 3D optical effect (in this case, the optical elements on the structural plate).

Fig.6 shows a diagram of the application for a compressed image composition based on the invention. When such a compression or stretch approach is used, at least one α_{ij} picture element can be displayed out of the partial information from at least two different A_k views (k=1... n) of the scene/subject mixed partial information. The applicant explains the impact of such approach in WO 03/024122.

An image composing sample for n=5 views can be seen at the left of Fig.6. However, the filter shown in Fig.2 requires preferably an image composition, which displays a horizontal series of 4 α_{ij} picture elements and a vertical series of 8 α_{ij} picture elements, while the displayed 5-view structure has one series of 5 or 10 α_{ij} picture elements. If the 5-view combination is to be used, it must be "bundled" with a width of 4 views and a height of 8 views.

This makes the picture compression possible, with which the partial information is occasionally assigned to picture elements and simultaneously to several views as a mixture. Referring to the theory from WO 03/024122, the density factors for the horizontal and vertical direction can be considered as dfx=dfy=5/4=1.25. In other words: A real picture element of the 17" LCD monitor usually displays a mixed image from the partial information of 1.25 partial informations. This is schematically illustrated in Fig.6: the right side section enlargement shows several α_{ij} picture elements from the image composition structure. A "real" picture element P would therefore display simultaneously partial information in accordance with the image combination structure of views 1 and 2 as a mixture; for example, a mixture of the partial information of views 2, 3 and 4 would be also possible.

Thus with the mentioned compression of the image composition, the desired series of image composition for the filter array is achieved on the LCD monitor or on the image rendering device. The preceding example serves only for explanation purposes. In practice other density factors, for example those lying between 1.1 and 1.4, will have a greater importance.

It is usually determined that it is beneficial to use the aforementioned compression or stretch approach, when one of the structural plates based on the invention, in particular filter arrays, are fitted over the image rendering device (LCD). For this, a given image composing structure is simply adapted to its series, this means suitably compressed or stretched, so that it is adequate for displaying the corresponding 3D optical effect (e.g. filter array).

In those applications of the invention with filter arrays, the use of transparent filter elements can also be foreseen, which can respectively display different outlines and/or inclinations.

Furthermore, the invention-based applications can also be used as complete or partial exchangeable surface overlays for displaying in 2D or 3D modes. Examples for such means are described in WO 2004/057878 and other writings.

The invention offers on the one hand the advantage that the arrangements and procedures of the initially mentioned kind of structure for the 3D optics for the normally sighted naked eye are designed to be indissoluble as far as possible. On the other hand, the visible dissolving of the 3D image is increased at the same time. Thus the quality of the spatially perceptible representation will improve and the undesired picture effects are minimized.